Sensors for Absolute UV-C Measurements and Long-Term Stability Tests

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This paper presents the use of ÖNORM UV sensors for absolute UV-C irradiation measurements and their evaluation. It shows the improvements of the new digital design as well as the results of in-field tests and long-time stability tests.

In most systems using UV-C, monitoring of UV-C irradiance is essential to ensure disinfection performance or to ensure the effect on photochemical processes. The Austrian national standard ÖNORM M 5873-1 [1] defines requirements for reference and duty sensors for use in drinking water disinfection systems using low pressure UV-C lamps. The upcoming standard ÖNORM M5873-3 further refines requirements on reference sensors. However, ÖNORM reference sensors can be used for other applications or in laboratory environments as they have high requirements on sensitivity and measurement accuracy. Besides that, UV sensors are typically exposed to rough environments. This especially applies for aging effects to the optical system as well as for the electrical signal processing under operation conditions.

The new generation of ZED UV-C sensors achieves significant improvements: more accurate signal processing to increase resolution and to expand the usable measurement range, better long-term stability, enhanced temperature stability and improvements to the optical system. To reach these goals ZED focused on digital signal processing inside the UV sensor, digital communication between sensor and measuring system and redesign of the optical system by using of new diffusing materials.

In order to measure germicidal effective radiation the UV sensor needs to detect radiation between 240..290nm. Low pressure mercury lamps emit radiation with a dominant spectral line of 253.7nm. Therefore, all radiation above 290nm shall not increase the value by more than 5%. ZED uses silicon carbide diodes together with a metal interference filter to gain the spectral sensitivity shown in (Fig. 1). Usage of a special achromatic quartz diffusor leads to an optical input characteristics that closely approximates the cosine which is mandatory for absolute irradiance measurements (Fig. 2). As required by ÖNORM the sensors are calibrated at 253.7nm.
To enable the sensors to measure UV-C radiation at different wavelengths, such as UV-C emitted by different UV-C LEDs, they can be modified for extended spectral sensitivity (Fig. 1). This is done by using different metal interference filters or by using a silicon carbide diode without filter. This leads to non-conformity to ÖNORM. As the sensitivity of silicon carbide diodes is wavelength dependent the sensor needs to be calibrated at the target wavelength. Alternatively, a normalized spectral response diagram can be provided.

ZED UV-C sensors employ a microprocessor based design with variable signal amplification and digital signal processing to allow precise measurements over a wide dynamic range (Fig. 3). ZED duty sensors reach an effective dynamic range of 17 bit while reference sensors use the advanced dynamic range of 20 bit to allow the measurement of irradiations starting at 0.005 W/m². For diagnostic purposes digital sensors incorporate an operation hour counter and a dose meter. The complete electronics is integrated in the sensor itself, measurement results are transmitted in W/m² digitally via RS485. No equipment except of the sensor itself needs to be calibrated.

ZED performed long term stability tests with the optical diffusor and with the complete sensor.
A number of 10 quartz diffusors were aged for 8000 hours by exposing it to UV-C of approx. 400 W/m². The results show that the quartz tends to become slightly more transmissible over dose (Fig. 4).
On the other hand, the complete sensor loses sensitivity. Analysis of recorded data of more than 900 duty sensors returned for recalibration confirmed that the measurement error rises with the UV-C dose (Fig. 5). Therefore UV-C sensors need to be recalibrated on a regularly basis, e.g. ÖNORM requires the reference sensors to be recalibrated every 100 operating hours or once a year.

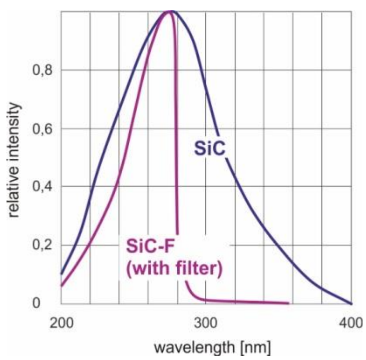

Fig. 1 spectral sensitivity of detector element

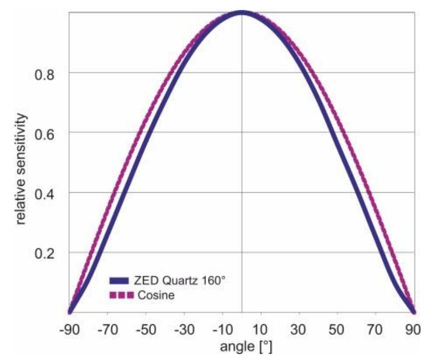

Fig. 2 spacial sensitivity of input optics

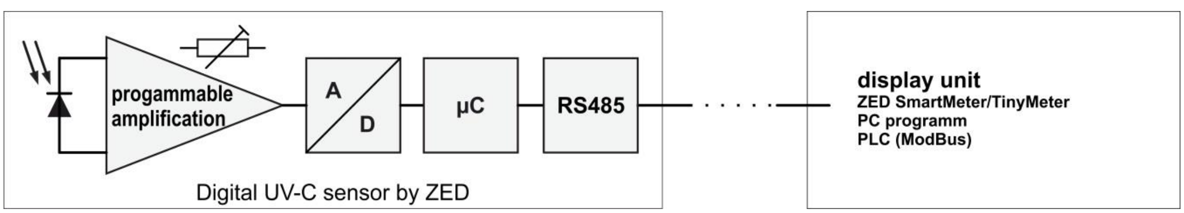

Fig. 3 block diagram ZED digital UV-C sensor

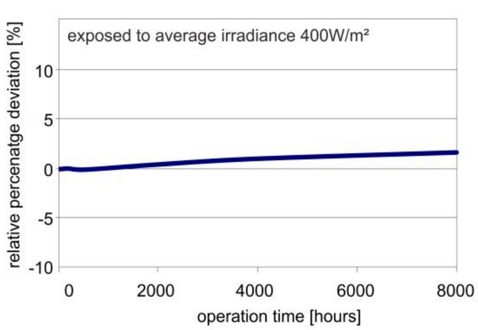

Fig. 4 average relative percentage deviation quartz optics over time

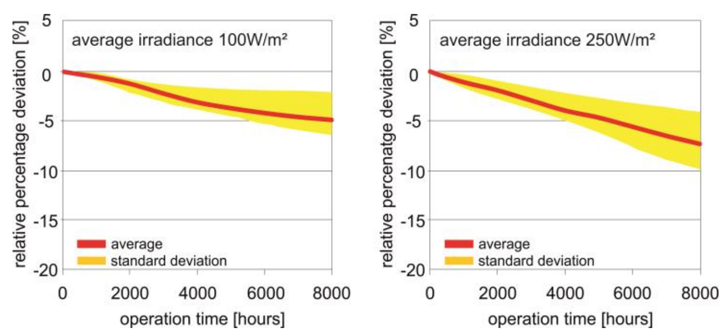

Fig. 5 relative deviation of UV-C sensors over time

References:

[1] ÖNORM M5783-1, Plants for disinfection of water using ultraviolet radiation – Requirements and testing – Low pressure mercury lamp plants, Österreichisches Normungsinstitut, 2001-03-01